ESTABLISHMENT OF SEEDED BLACK LOCUST ON SPOIL BANKS

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Establishment of Seeded Black Locust on Spoil Banks

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Introduction

STRIP mining of coal began in West Virginia on a small scale prior to World War I. However, it was not until 1940 that stripping operations contributed substantially to the total tonnage of coal produced in the State. During World War II and immediately thereafter, stripping operations were expanded greatly, with the peak being reached in 1947 when stripping contributed 12.5 per cent of the total coal produced in West Virginia (Myers 1950). Since that time, stripping has decreased slightly, until at present it contributes approximately 10 per cent of the annual output of coal in West Virginia.

As of December 1, 1959, approximately 70,000 acres had been affected by strip-mining operations in West Virginia. At the present rate of stripping, approximately 2,000 acres are being added to this figure annually.

Strip mining consists of uncovering a coal seam, piling the overburden to one side, and then removing the coal. The unsightly, newly-formed spoils are commonly made up of rock fragment and slabs, intermixed with varying amounts of finer rock particles and soil. Usually the original surface soil is buried and forms little or no part of the new surface. A cross section of a typical spoil area is shown in Figure 1. Initially, the spoil is bare of vegetation. This may cause increased runoff of water, erosion, stream pollution, and landslides and slips. Revegetation is needed to stabilize these areas and return them to a productive condition.

Most of the spoils are capable of supporting vegetation following completion of strip mining operations. A small percentage of the total spoil bank area in the State is too acid to support vegetation. Other areas having long, extremely steep slopes constitute difficult sites for seedling establishment, and vegetation on such sites may be sparse for several years following completion of stripping.

The first legislation regulating strip mining in West Virginia became effective in January 1941 and required regrading of the spoil area

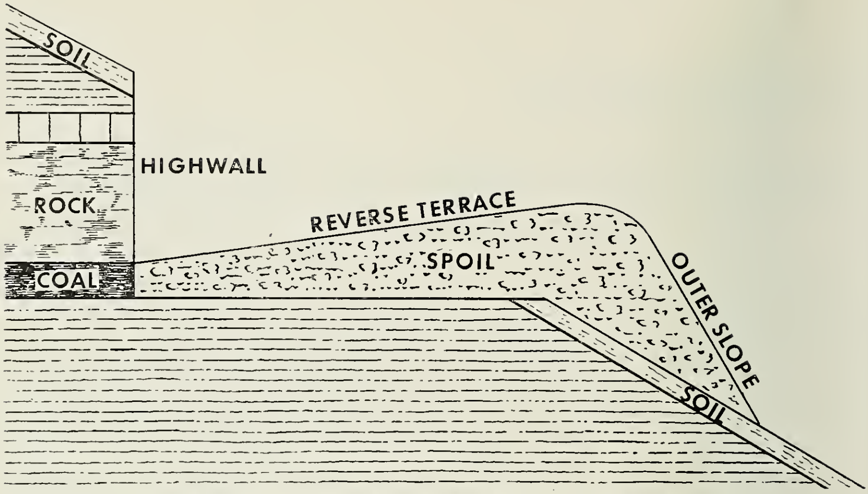


FIGURE 1. Cross section of typical spoil area following regrading.

but did not require any planting or seeding (*Acts of W. Va. Legislature* 1939). Some 15,000 to 20,000 acres in West Virginia came under this law. Amendments, enacted in 1945, provided for the regrading of agricultural lands affected by stripping and also required that the area be planted or seeded with trees, shrubs, grasses or vines (*Acts of W. Va. Legislature* 1945). Approximately 50,000 to 55,000 acres of stripped lands in West Virginia were covered by this law.

In West Virginia, direct seeding has been the most common method employed to artificially revegetate strip-mined areas. Approximately 60 per cent of the spoil area on which direct seeding has been used was seeded with grasses or herbaceous legumes. The remaining 40 per cent was seeded with black locust.

The purposes of this study were: (1) To determine the success of establishment of direct-seeded black locust on spoil banks in West Virginia; (2) To determine the amount and type of woody species established naturally on spoil bank areas; and (3) To attempt to determine the factors of site which were effective in bringing about success or failure of establishment of seeding on spoil bank areas.

Procedure

A list of all strip-mined areas in West Virginia on which black locust had been seeded from two to ten years previously was obtained through examination of records made available by the State Agriculturist. This list comprised approximately 800 individual spoil banks. From

each record, information was taken concerning location and ownership of the property, length and total area of stripping, species and amount of seed used in revegetation, and the date of seeding. The list of stripping was then separated by counties, and, in a random manner, 10 per cent of the areas in each county were selected for individual examination on the ground. In any county having less than ten spoil bank areas which had been seeded with black locust, one area was selected for sampling. This system of selection was used so that the sampling areas would be distributed over the wide range of spoil conditions that occur in different parts of the State, and so that those counties with the largest number of spoil banks seeded with black locust would be sampled the heaviest. The estimates obtained from this sample should be representative of all spoil banks in West Virginia that have been seeded with black locust. Only in those counties where several areas were sampled will it provide a reasonable estimate of the conditions within that county. Using these criteria for selection, 81 strip-mined areas were selected for individual examination.

After one of the selected spoil banks had been located on the ground, general information about it was taken concerning topography, spoil material, exposure, and natural seed source. In addition, the area was systematically sampled using milacre plots as the sampling unit. On each plot, the number of black locust seedlings and the species and number of natural woody seedlings were tallied, and an ocular estimate was made of the amount and type of herbaceous cover on the plot. Also, the aspect and degree of slope of each plot was determined. On each spoil bank, four spoil samples were collected at random. From these samples, stoniness and pH were determined.

Results

Prior to beginning the study it was not known whether there would be differences in the amount and distribution of vegetation occurring on the reverse terrace and the outer slope of the spoil banks. Therefore the data were summarized for the reverse terrace, the outer slope, and for the total spoil. As shown in Table 1, tests indicated that the reverse terrace and outer slope were not statistically different. This was true for both the controlled seeding of black locust and for the natural seeding by woody species. This indicates that the amount and distribution of reproduction are essentially the same on the reverse terrace and outer slope. Therefore, the data for the two portions were combined and considered together in analyzing all data. In discussions that follow, where data are presented, it will be applicable to the entire spoil area that was sampled.

TABLE 1. RELATIONSHIP OF REPRODUCTION ON REVERSE TERRACE AND OUTER SLOPE OF STRIP MINE SPOIL

	Mean Values*		Diff. in Means	Degrees of Freedom	Correlation Coefficient Values	t-value : Test of Difference Between Means of OS & RT
	Outer Slope	Reverse Terrace				
	CONTROLLED SEEDING OF BLACK LOCUST					
Number of Seedlings per acre	466.6	448.7	17.9	79	0.535**	0.303†
Per cent Stocking	40.1	37.5	2.6	79	0.321**	0.155†
	NATURAL SEEDING OF WOODY SPECIES					
Number of Seedlings per acre	754.7	628.5	126.2	79	0.657**	1.614†
Per cent Stocking	54.5	45.6	8.9	79	0.644**	0.523†

*The mean values as here presented are averages based on individual spoils and are not weighted according to the acreage of each individual spoil bank.

**Values are significant at the 1 per cent level.

†Values are not significant.

ESTABLISHMENT OF DIRECT-SEEDED BLACK LOCUST

Where the need for cover is the primary consideration in reclaiming strip-mined areas, black locust is probably the best tree species which can be used to accomplish this purpose. It has the ability to become established on difficult sites, produces seed at an early age and puts down a large amount of litter. It also grows fast and its' spreading crown form gives crown closure and cover at an early age (Chapman 1944). In addition, locust is a legume and can add nitrogen to the soil. This is especially important since nitrogen is one primary element that is usually deficient on most spoil bank areas (Chapman 1947).

On the spoil bank included in this sample, there was much variation in the abundance or number of black locust seedlings which resulted from the direct seeding on the different sites. For example, three areas sampled had no seedlings which resulted from the direct seeding of locust, whereas one area, Ohio 1, had more than 2,000 seedlings per acre. There was an average of 464 black locust seedlings per acre on all spoil banks sampled. The amount of sampled spoil bank area in each abundance class is shown in Figure 2. For any particular spoil bank, the number of seedlings per acre may be found in Appendix Table 1.

The percentage of stocking or distribution of seedlings also showed considerable variation. Three of the areas examined had zero per cent stocking, and others had varying degrees of stocking, ranging up to 83 per cent on Mercer 1. The average stocking for the entire sample was

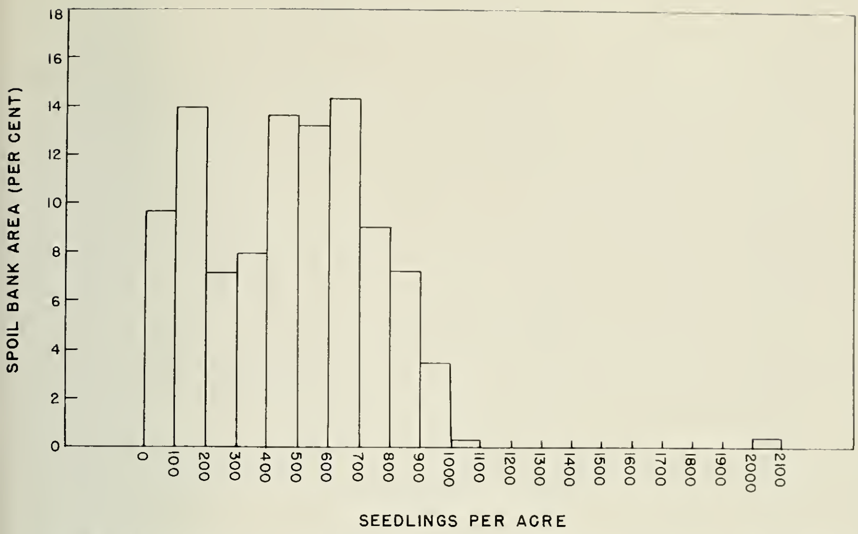


FIGURE 2. Abundance, by classes, of direct-seeded black locust on spoil banks.

40.0 per cent. The proportion of spoil bank area in each stocking class is shown in Figure 3. For any particular sampled area, stocking may be found in Appendix Table 1.

In order to evaluate the success of direct-seeded black locust in providing cover on spoil areas sampled in this study, a method was devised whereby each spoil bank area could be classified as a success, a partial success, or a failure. The principal factors used in developing this system were age and size of the seedlings, number of seedlings per acre, and percentage of the area on which the seedlings occurred (per cent stocking). The set of curves presented in Figure 4 has been developed using these criteria. A more detailed explanation of the method of construction is contained in the Appendix.

The success of establishment on each spoil bank was then determined using Figure 4. An example of the method of using this Figure in determining degree of success follows: A spoil bank seeded with black locust four years ago had 450 seedlings per acre occurring on 40 per cent of its area (40 per cent stocking). Using Test 1, the point representing 450 four-year-old seedlings would fall in Area F. Using Test 2, a per cent stocking of 40 for that age would also fall in Area F. Area F is one of the two areas indicative of a "Partial Success." Therefore, that spoil bank would be rated as a partial success with respect to black locust establishment. Had *either* the number of seedlings under Test 1 or per cent stocking under Test 2 fallen in a lower area (G or H), that

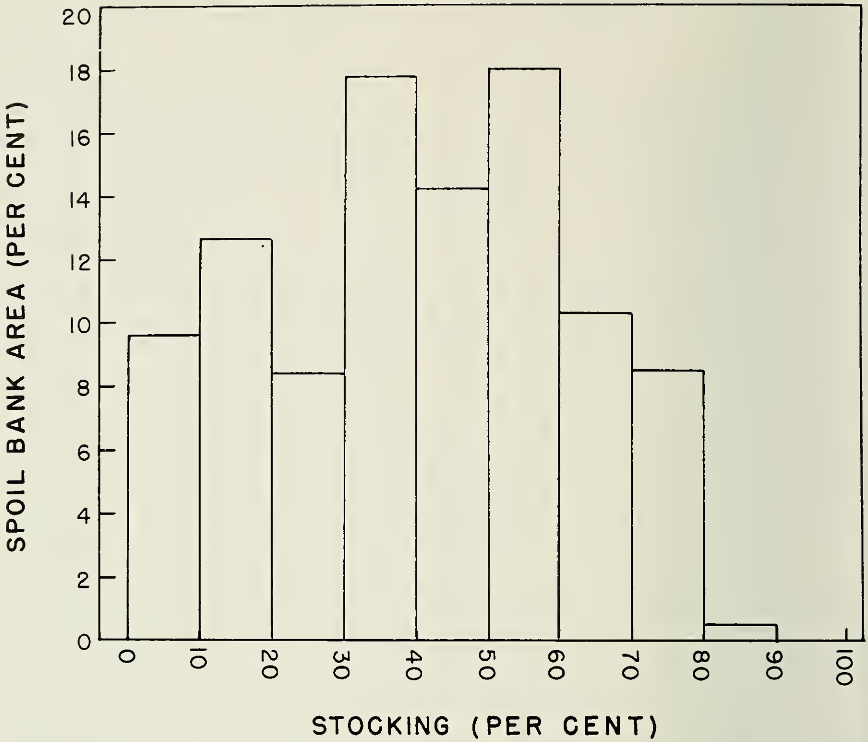
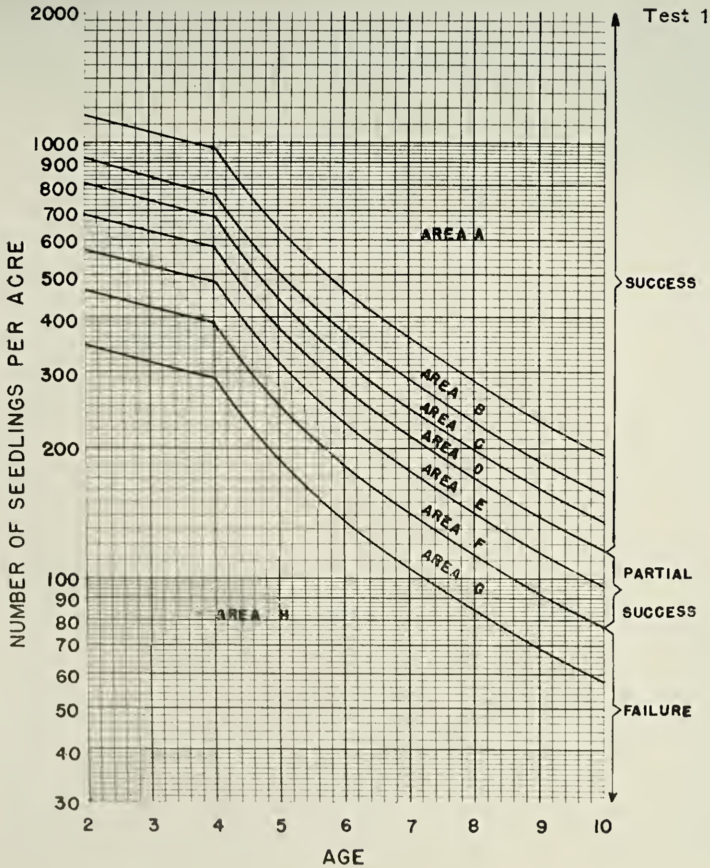


FIGURE 3. Stocking, by classes, of direct-seeded black locust on spoil banks.

area would have been used to determine the degree of success, and a failure would have been indicated.

A summary of the evaluations obtained in this way is continued in Table 2. As indicated in Table 2, direct seeding of black locust has provided adequate cover on approximately 20 per cent of the spoil bank area on which it has been used. On nearly 50 per cent of the area, the seedings were failures. The remaining 30 per cent ranges between success and failure. Figures 5 and 6 show areas on which direct seedings of black locust were a success and a failure.

Where the need for cover is the primary consideration, distribution of seedlings is often a limiting factor for determining the degree of success in evaluating the direct seeding on a spoil bank. A spoil bank may have a relatively large number of trees per acre, but if those seedlings are grouped on a small portion of the area, they are not providing adequate cover on that area. Therefore, in evaluating the spoil areas,



Test 1: Based on Number of Black Locust Seedlings Per Acre.

Test 2: Based on Per Cent Stocking of Black Locust Seedlings

Area	Per Cent Stocking Needed for Success in Area Indicated	Degree of Success
A	100	Success
B	80-99	
C	70-79	
D	60-69	
E	50-59	Partial Success
F	40-49	
G	30-39	Failure
H	Less than 30	

FIGURE 4. Curves and Table for Determining Success of Establishment for Seeded Black Locust on Spoil Banks.
In Test 1, the area in which the spoil bank is classified is determined, for a given age, by the number of seedlings per acre.
In Test 2, the area in which the spoil is classified is determined by per cent stocking.
Areas A, B, C, and D indicate successful establishment.

Areas E and F indicate partial success.

Areas G and H indicate failure of establishment.

FIGURE 5. Successful establishment of seeded black locust. This excellent stand of black locust occurs on a spoil in Ohio County. The area was direct-seeded in 1953. When sampled in 1958, the locust were nine feet tall and averaged more than 2,000 trees per acre.

some met standards of success as far as number of trees per acre was concerned but did not meet adequate standards of distribution. This was true on 40 of the 81 spoils evaluated. For example, Mercer 2 had 652

TABLE 2. SUCCESS OF ESTABLISHMENT OF DIRECT-SEEDED BLACK LOCUST

CURVE AREA	NUMBER OF ACRES IN CURVE AREA	PER CENT OF TOTAL ACREAGE IN AREA	SUCCESS OF ESTABLISHMENT
A	0.0	0.0	Success
B	10.4	0.6	
C	155.6	8.5	
D	195.8	10.7	
Totals	361.8	19.8	
E	320.2	17.6	Partial Success
F	259.0	14.2	
Totals	579.2	31.8	
G	319.2	17.5	Failure
H	563.2	30.9	
Totals	882.4	48.4	
Grand Totals	1,823.4	100.0	

FIGURE 6. Failure of seeded black locust. This spoil in Brooke County was seeded in 1949. When sampled in 1958, the area had less than 100 trees per acre. The trees averaged 13 feet in height.

seedlings per acre, nine years of age and distributed on 56 per cent of the area. Using Figure 4, based on the number of seedlings, this area would fall in curve area A. However, the 56 per cent stocking lowers the spoil to curve area E, a partial success. Such an area is shown in Figure 7. On 41 of the 81 spoils, abundance and stocking indicated the same degree of success.

It should be emphasized that success or failure of seeding is not a definite value. For purposes of evaluating the results of this study, number of seedlings per acre, which varied with age, and per cent stocking values of 60 per cent and above for success, 40 to 59 per cent for partial success, and below 40 per cent for failure were used as standards. Appendix Table 1 contains the pertinent data obtained for each individual spoil bank area that was sampled. By using these data, the abundance and distribution of seeded black locust falling within any given set of standards which might be set up can be determined.

ESTABLISHMENT OF NATURALLY-SEEDED WOODY SPECIES

Woody seedlings other than the direct-seeded black locust are usually found on the spoil bank areas when tree and shrub species occur on

FIGURE 7. Erratic grouping of clumps of seeded black locust and bare areas determined the partial success rating given to this area.

lands adjoining the strip-mined sites. As shown in Table 3, 37 different species occurred on the spoils sampled in this study. Almost all of this reproduction was represented by species whose seed is either wind or bird disseminated. Only about 1 per cent of the total reproduction was made up of heavy-seeded species, and these seedlings were usually found around the edges of the spoil areas.

Approximately one-third of the total reproduction was represented by black birch, and more than one-half was made up of black birch, black locust and red maple. Of the 37 species found on the banks, 22, contributing 78 per cent of the total reproduction, were considered to have little or no commercial value. The species which made up more than 1 per cent of the total reproduction, included black birch, black locust, sycamore, sassafras, fire cherry, sumac, and willow. Fifteen species, contributing only 22 per cent of the total reproduction, were considered to have potential commercial value. The species making up more than 1 per cent of the total reproduction included red maple, yellow-poplar, pitch pine, and sugar maple.

TABLE 3. WOODY SPECIES NATURALLY ESTABLISHED ON SPOIL BANKS

Species	Spoil Banks Stocked With Indicated Species (per cent of Spoil Banks)	Abundance of Natural Reproduction (per cent of Total)
Black birch	54.3	31.75
Black locust	59.3	13.69
Red maple	58.0	10.61
Sycamore	39.5	8.35
Sassafras	39.5	8.18
Yellow-poplar	51.9	7.29
Fire cherry	19.8	5.32
Sumac	40.8	5.18
Willow	18.5	2.57
Pitch pine	2.5	1.73
Sugar maple	12.4	1.43
Slippery elm	7.4	0.60
Flowering dogwood	3.7	0.59
Trembling aspen	8.6	0.51
White ash	6.2	0.33
Red oak	3.7	0.29
Elderberry	2.5	0.28
Chestnut oak	3.7	0.17
Striped maple	2.5	0.17
Black cherry	3.7	0.15
Hickory	3.7	0.12
American beech	2.5	0.12
Blackgum	3.7	0.11
Crab apple	1.2	0.10
Virginia pine	1.2	0.07
Yellow birch	1.2	0.07
Black oak	1.2	0.06
Red bud	1.2	0.05
White pine	1.2	0.05
Hornbeam	1.2	0.04
Green ash	1.2	0.03
Serviceberry	1.2	0.03
Ailanthus	1.2	0.03
Hercules club	1.2	0.02
Honey locust	1.2	0.02
Alder	1.2	0.01
Hawthorn	1.2	0.01
Total	------	100.00

The average abundance of natural seedlings for the entire spoil area was 684 seedlings per acre, and the average distribution was 49.7 per cent. As shown in Figures 8 and 9, there is considerable variation in the abundance and distribution of these natural seedlings on different strip-mined areas. Appendix Table 2 contains the data for each individual spoil.

As might be expected, the abundance and distribution of seedlings resulting from natural seeding was higher than that obtained from the direct seeding of black locust. This is accounted for by the fact that the natural seedlings are the result of repeated seedings over a period of years beginning immediately following completion of stripping on an area, whereas the direct-seeded black locust was sown but once.

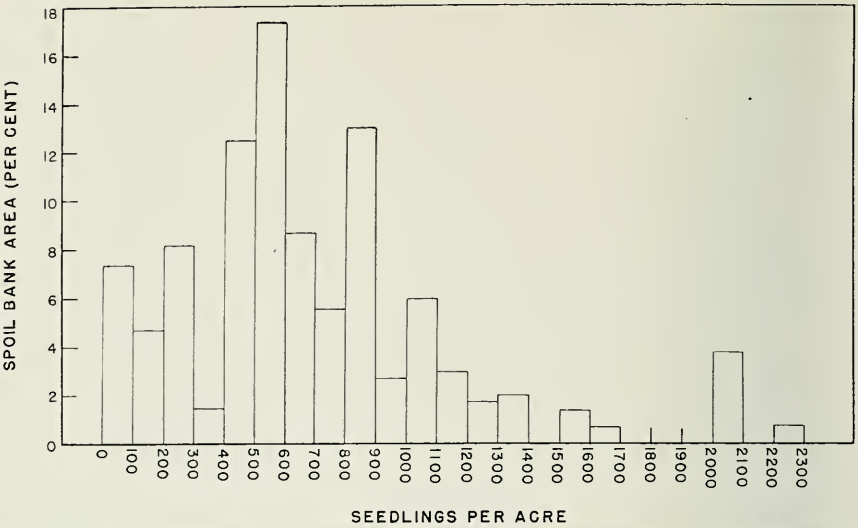


FIGURE 8. Abundance, by classes, of naturally-established woody species on spoil banks.

Although the number of naturally-established seedlings coming in on spoil banks is often quite high, consideration of only abundance and distribution of these species is often misleading if cover and stabilization are the objects of revegetating the areas. Most of the natural species seeding in are slower growing and have narrower crowns than black locust and thus do not give crown closure and cover as quickly as does locust. The amount of litter provided is not nearly as great as that produced by black locust; and it was observed that even in many rather dense stands of natural reproduction, ground cover and litter were almost completely absent. This is in keeping with the findings of Chapman (1944) in Ohio. In addition, these species do not have the ability to add nitrogen to the soil, an important consideration in building up desirable spoil properties on the spoils.

Even if a volunteer stand of timber does develop on stripped lands, the trees may not be suitable for production of a quality product. Since the trees are the result of seeding in over a period of years, they tend to be open-grown, short-boled, and limby. Deitschman and Lane (1952) found that such trees growing on strip areas normally contain one 16-foot log or less.

In many respects, natural stands which become established on spoil banks are similar to stands found on old-field sites. Both usually consist of species whose seed is wind- or bird-disseminated, and which often have little or no commercial value. Also, stands on both areas are usually the

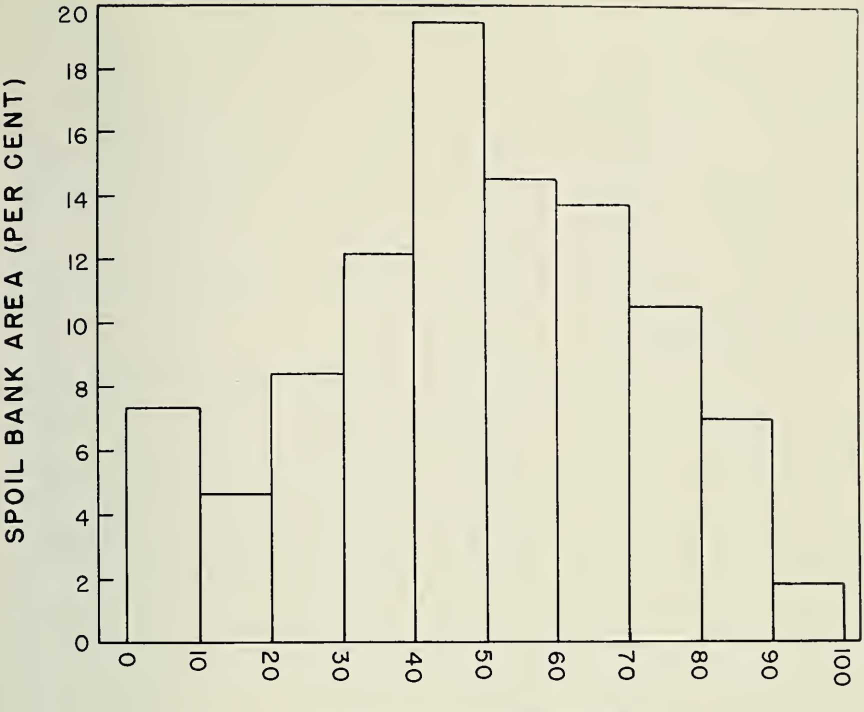


FIGURE 9. Stocking, by classes, of naturally-established woody species on spoil banks.

result of seeding in over a period of years, and the trees tend to be open-grown and limby. One major difference in the character of stands on spoil banks and on old fields is that on strip-mined areas, because of the extreme variability in spoil material, stands tend to be grouped on portions of the spoil bank, whereas on old fields, distribution of trees is usually fairly uniform over the entire area.

SITE FACTORS AFFECTING THE ESTABLISHMENT OF VEGETATION ON SPOIL BANK AREAS

Many factors affect establishment of vegetation on strip-mine areas throughout the State. Of the factors included in this study, acidity of spoil material, time of sowing of black locust seed, low summer precipitation, and percentage of slope showed a relationship to the establishment of vegetation on the spoils. Other factors investigated, including aspect and stoniness of spoil material, showed no relationship to the establishment of vegetation in this survey-type study.

One major difficulty was encountered in attempting to evaluate the factors affecting the establishment of direct-seeded black locust on an area. No information was available concerning the seedlots used in the different seeding operations, and viability of the seed may well have varied considerably from one job to another. In addition, it is possible that one person may have done a better job than another in distributing the seed evenly over the entire spoil area, which, as previously discussed, is very important in determining the amount of cover provided.

EFFECT OF ACIDITY OF SPOIL MATERIAL ON ESTABLISHMENT OF VEGETATION

Acidity of spoil material in many cases is one of the most important factors affecting the establishment of vegetation on strip-mined areas. It is generally considered that little or no plant growth will occur on soil having a pH less than 4.0 (Croxton 1929, Limstrom 1948). Fortunately, the amount of spoil area in West Virginia in this extremely acid class is relatively small, being less than 7 per cent of the spoil sampled in this study, as shown in Table 4. This figure agrees closely with the findings of Potter, *et al.* (1951).

Table 5 gives a summary of the data obtained from 289 sample plots on which vegetation was measured and spoil acidity was determined to the nearest 0.1 pH unit. As may be seen from this table, vegetation, either woody or herbaceous, is very sparse on areas having a pH less than 4.0. Above this point there is a definite correlation between the number of woody seedlings per acre and soil pH. As shown in Figure 10, direct-seeded black locust increased by 184 seedlings per acre for each

Table 4. Distribution of Sampled Spoil Bank Area by pH Class

Classification	pH Range	Acreage	Per Cent of Total Acreage
Extremely Acid or Toxic	2.5-2.9	9.5	0.52
	3.0-3.4	20.9	1.15
	3.5-3.9	89.5	4.91
	Totals	119.9	6.61
Acid	4.0-4.4	212.3	11.61
	4.5-4.9	368.3	20.20
	5.0-5.4	701.4	38.46
	5.5-5.9	297.4	16.33
	6.0-6.4	74.0	4.06
	6.5-6.9	38.8	2.13
	Totals	1692.5	92.79
Calcareous	7.0-7.4	9.7	0.53
	7.5-7.9	1.3	0.07
	Totals	11.0	0.60
Grand Totals		1823.4	100.00

Table 5. Relationship Between pH and Vegetation on Sample Plots

Classification	pH Class	Av. pH	No. of Plots	Vegetation on Plots		
				Black Locust/Acre	Natural Seedlings/Acre	Per Cent Herb. Cover
Extremely Acid	2.5-2.9	2.85	2	0	0	0
	3.0-3.4	3.28	5	0	0	7
	3.5-3.9	3.72	16	0	63	5
Acid	4.0-4.4	4.24	49	490	550	48
	4.5-4.9	4.72	64	375	687	48
	5.0-5.4	5.18	90	556	722	51
	5.5-5.9	5.68	34	618	824	48
	6.0-6.4	6.21	15	733	800	51
	6.5-6.9	6.68	11	1000	1000	55
Calcareous	7.0-7.4	7.15	2	1000	1000	25
	7.5-7.9	7.70	1	0	0	85

1.0 unit increase in pH. This regression was significant at the 5 per cent level. Natural seedlings increased by 157 per acre for each 1.0 unit increase in pH. This regression was significant at the 1 per cent level.

Most of the hardwood species, including black locust, which are becoming established on spoil banks in West Virginia have a preferred pH range above 6.0 according to pH preferences of plants as published

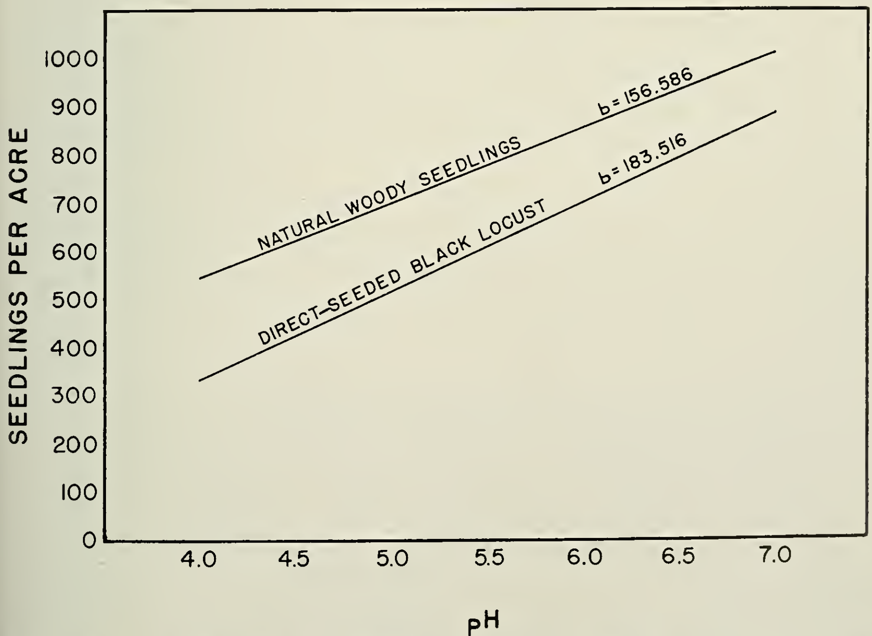


FIGURE 10. Relationship (regression) of woody seedlings to pH on 263 sample plots with pH of 4.0 to 7.0.

by Spurway (1941). This preference probably accounts for the upward trend in establishment of tree seedlings as pH increases from 4.0 to 7.0.

As shown in Table 5, the amount of herbaceous cover occurring on plots having pH 4.0 and above is fairly constant. This even distribution is probably the result of a wide range of pH preferences of the most common herbaceous plants becoming established on the spoil area. Some of the most common species encountered in this study were broomsedge, poverty-grass, panic-grass, cinquefoil, goldenrod, pokeweed, sericea lespedeza, and redtop. For the entire sampled spoil area, the average herbaceous cover was 37 per cent.

EFFECT OF TIME OF SOWING BLACK LOCUST SEED ON SEEDLING ESTABLISHMENT

The importance of the time of year, or month of seeding, on the establishment of black locust seedlings on spoil banks was evaluated in an attempt to determine if any month or months gave better results. The number of seedlings obtained from a pound of seed was calculated for each spoil and related to the month sown. The results are presented in Table 6. Three of the 81 spoils were not included because of low pH. Low pH hinders establishment of seedlings.

Although the results cannot be considered as entirely reliable because of the use of different seedlots and probable differences in methods of sowing, they do show better establishment in some months than in others. Also, only two of the spoils sampled were sown in January and none in February.

Black locust seed sown during the months of November, December, and March gave the best seedling establishment. It seems likely that the period November through March might represent a suitable time for sowing black locust seed on the spoil banks.

TABLE 6. BLACK LOCUST SEEDLING ESTABLISHMENT BY MONTH SOWN (AVERAGE NUMBER OF SEEDLINGS PER POUND OF SEED SOWN)

Month Sown	Average Number Seedlings Per Pound of Seed	Number of Spoils	Month Sown	Average Number Seedlings Per Pound of Seed	Number of Spoils
January	65	2	July	58	1
February	----	0	August	86	3
March	121	11	September	89	5
April	75	16	October	109	7
May	84	21	November	146	3
June	101	7	December	171	2

EFFECT OF LOW SUMMER PRECIPITATION PERIODS ON SEEDLING ESTABLISHMENT

An attempt was made to determine if different amounts of precipitation during the germination period and first growing season affected establishment of black locust seedlings originating from direct seeding on the spoil banks.

Only 64 of the 81 banks sampled were used in this phase of the study. Those not used were excluded on the basis of lack of suitable weather records or low pH.

No relationship could be found between number of black locust seedlings and precipitation during selected periods (U. S. Weather Bureau, 1948-1957) including the month germination should occur, and longer periods, as the next month, the next two months, and finally the next three months.

Next, an attempt was made to determine if periods of low precipitation approximating near drought or drought conditions during the first growing season had an effect on number of seedlings on the spoils.

Near drought or drought conditions were considered to occur any month during the warm growing season when the precipitation for that month was less than 2.00 inches. This general figure was selected after considering precipitation and drought (Tannehill, 1946) and drought periods in one section of the State (Tryon & True, 1958).

The results are shown in Table 7. The average number of seedlings per pound of seed was 105.5 for those first growing seasons when no low precipitation periods occurred. With a near drought or drought conditions occurring in one or more months during the first growing season, the number of seedlings dropped 22 per cent, or to 81.8 per pound of seed sown. Further consideration was given to the effect of low precipitation during the month the black locust would be expected to germinate, and followed by a near drought or drought later that summer.

Table 7. Black Locust Seedlings on Spoil Banks Related to Low Summer Precipitation Periods

Moisture conditions during first growing season	Number of seedlings per pound of seed	Number of Spoil Banks
Spoils without low precipitation period	105.5	39
Spoils with one or more low precipitation periods	81.8	25
Spoils with low precipitation during first month* followed by a low summer precipitation period	44.7	6

*First month refers to the month when the majority of germination should occur following seeding.

An even greater reduction in seedlings occurred; they were reduced by 58 per cent, or to 44.7 per pound of seed.

Thus low precipitation periods considered to be either near droughts or droughts during the first growing season reduced the number of surviving black locust seedlings. More than one such low precipitation period during the same season did not seem to reduce the number of seedlings more than a single drought or near drought.

EFFECT OF STEEPNESS OF SLOPE ON ESTABLISHMENT OF WOODY SEEDLINGS

The effect of steepness of slope on establishment of direct-seeded black locust and natural woody seedlings was studied on 840 milacre plots. These plots had not been subjected to grading and had slopes ranging from 30 to 95 per cent. Figure 11 contains a summary of the results obtained in this study. Generally, this figure shows that the number of established woody seedlings decreased as percentage of slope increased.

The number of black locust seedlings decreased slightly on slopes ranging from 30 to 75 per cent; this decrease being from 500 seedlings per acre at 30 per cent to approximately 425 per acre at 75 per cent

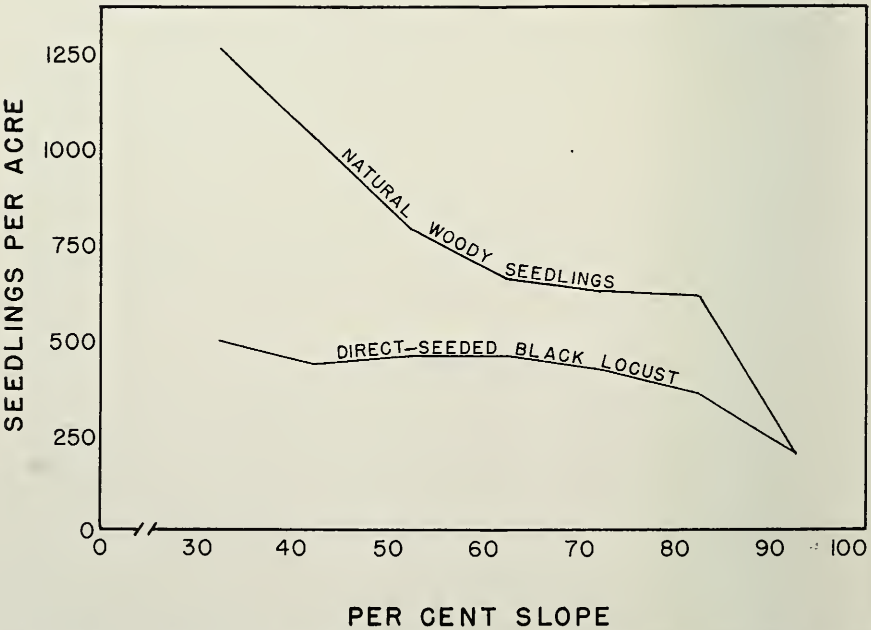


FIGURE 11. Relation of establishment of woody seedlings to per cent slope on 840 sample plots having slopes of 30 to 95 per cent.

Above 75 per cent, the rate of decline in number of seedlings became greater, and at 95 per cent, the maximum slope measured, there were approximately 200 established black locust seedlings per acre.

The number of established natural woody seedlings declined sharply at a fairly constant rate on slopes ranging between 30 and 65 per cent. This decrease was from 1,250 seedlings per acre at 30 per cent to approximately 650 per acre at 65 per cent. On slopes of 65 to 85 per cent, there was only a slight decrease in the number of established seedlings, the decrease being to 625 per acre on slopes of 85 per cent. This change in the rate of decline of number of seedlings on slopes of 65 to 85 per cent was the result of a few plots in each slope class being very heavily stocked. (For instance, one milacre plot with a slope of 70 per cent had eight established natural seedlings.) Above 85 per cent slope, the rate of decline in number of established seedlings was greater, and at 95 per cent, there were approximately 200 natural woody seedlings per acre.

This study did not include any of the extremely long, steep slopes common in some of the counties in the south-central part of the State. Many of these areas have slopes of more than 100 per cent and may be one-fourth mile or more in length. It is almost impossible to seed or plant these areas because of their extreme slopes. Because of their length, it is impossible to distribute seed over the entire area from a point near the top, and they are even inaccessible to an adequate natural seed source. Thus, they may remain nearly bare of vegetation for several years following completion of stripping. Such an area is shown in Figure 12.

Summary

Strip mining of coal has directly affected approximately 70,000 acres of land in West Virginia. Since 1945, law has required that stripped areas be revegetated. In West Virginia, direct seeding has been the most common method of artifically revegetating spoil banks.

A survey was made of randomly-selected spoil banks throughout the State on which black locust had been direct seeded. Investigation of the vegetation, including direct-seeded black locust and natural vegetation, and site factors on those areas indicated the following:

1. An evaluation of the effectiveness of direct seeding of black locust in providing cover on spoil bank areas indicated that on 20 per cent of the area, adequate cover had been provided; on nearly 50 per cent of the area, the seedings had been failures and adequate cover had not been provided; on the remaining 30 per cent of the area, seedings ranged between success and failure.

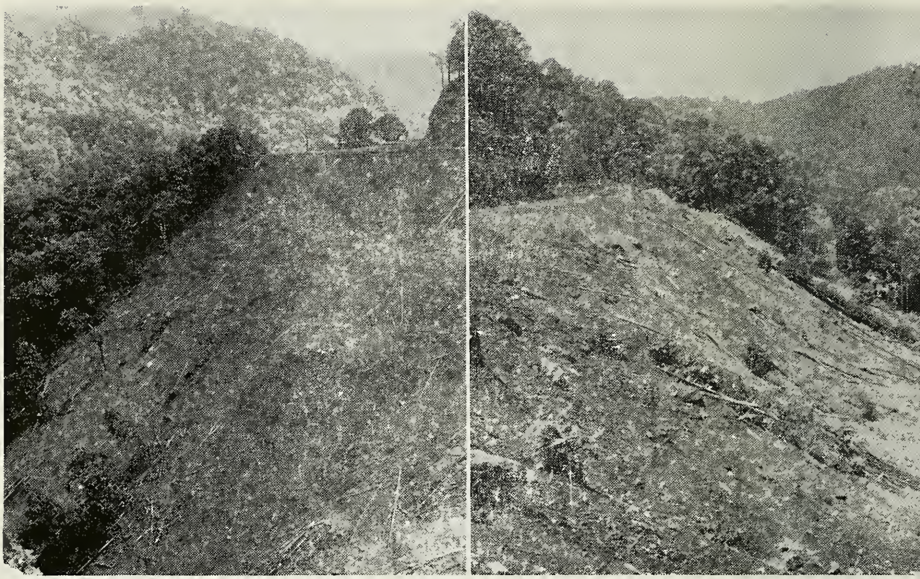


FIGURE 12. This spoil area, located in Fayette County, was strip mined in 1956 and 1957. Slopes on the area vary from 85 to 120 per cent and are up to 1,000 feet in length. It may be noted that there is very little vegetation established on the slopes.

2. Direct seeding of black locust resulted in an average abundance of 464 seedlings per acre and an average distribution or per cent stocking of 40.4 per cent on the spoil areas in West Virginia. On individual spoils, abundance varied from 0 to 2,000 seedlings per acre. Distribution of seedlings ranged from 0 to 83 per cent.

3. In all, 37 different woody species were found to be seeding in naturally on spoil bank areas throughout the State. Approximately 78 per cent of the natural reproduction consisted of species which have little or no commercial value. The average abundance of natural seedlings was 684 trees per acre, and the average distribution was 49.7 per cent. Because of slower growth, narrower crowns, and less litter produced, most of these natural species will not provide as good cover and stabilization as black locust. When a natural stand does develop on spoils, the trees are often of poor quality.

4. The study of vegetation on 289 sample plots showed a definite correlation between soil pH and vegetation. Below pH 4.0 there was little or no vegetation occurring on the areas. Fortunately, only about 7 per cent of the spoil area sampled was found to be in this extremely acid class. At pH 4.0 and above, woody seedlings, mainly hardwoods, increased in direct relationship to the increase in pH. This increase was

probably due to a preference for the higher pH values by most of the woody species becoming established on the spoils. Herbaceous vegetation, on the other hand, was fairly constant on areas having pH 4.0 and above. This is the result of a wide variety of pH preferences of the most common herbaceous species coming in on spoil banks. The average herbaceous cover for all spoil area was 37 per cent.

5. November through March seemed to be the best period for direct seeding of black locust.

6. Low precipitation periods, considered to be either droughts or near droughts, which occurred during the first growing season were found to reduce the number of surviving black locust seedlings. More than one such low precipitation period during the same growing season did not seem to further reduce the number of seedlings.

7. The study of woody seedlings established on 840 milacre plots having slopes of 30 to 95 per cent generally showed that as per cent slope increased, the number of established seedlings on the area decreased. Direct-seeded black locust decreased from approximately 500 per acre on 30 per cent slopes to 200 per acre on 95 per cent slopes. Natural woody seedlings decreased from nearly 1,250 seedlings per acre on slopes of 30 per cent to only 200 per acre on slopes of 95 per cent.

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APPENDIX

METHOD OF DETERMINING SUCCESS OF ESTABLISHMENT OF DIRECT-SEEDED BLACK LOCUST

In order to be able to evaluate the degree of success of establishment of direct-seeded black locust on spoil banks, a method has been devised for use in this study. This method is based on the *total number of seedlings per acre of different ages, and per cent stocking.* The number of seedlings required for successful establishment will not always be the same for all situations and is somewhat subject to personal judgement. The number, representing successful establishment, will vary with age and size of the tree, and particularly crown size in this instance.

The most commonly used single factor for determining success of tree seedling establishment is the number per acre. This factor, as used here, has been based on the number of evenly-spaced seedlings which can occupy the area. Crown width is the limiting factor in determining the number of evenly-spaced locusts needed to fully occupy the area, and the number will vary with age of the locusts and, in turn, with their height.

The first step in determining the number of evenly-spaced locusts needed to occupy the area was to measure the total height and crown widths of open-grown black locusts covering the range of heights occurring on the spoil banks sampled. Next, crown diameters by heights were plotted, and a curve fitted. By use of the curve, the average crown diameter for each height was determined.

The height of each black locust was plotted by age, and a curve fitted. From this curve, the average height of black locusts of any designated age, within the range of the sample, could be determined. The range of heights within any age class was broad, resulting from extremes of productivity of the spoil material. Then crown diameters were plotted over age, and a curve fitted so that average crown diameters for each age could be found.

The next step was to calculate the number of black locusts, evenly spaced, which would have their crowns touching on six sides within hexagonal figures fully occupying the area. Such a condition is considered ideal stocking and means that 91 per cent of the surface would be shared or covered by the crowns. This calculation was made for crowns of average size in each age class. The number of black locusts per acre required to give such a crown density at ages from two to ten, is shown by the uppermost curve in Figure 4, Test 1. This curve is considered to represent the

minimum number of evenly-spaced locusts required to give ideal stocking for average-sized black locusts from two to ten years old on the spoil banks.

The change of trend in the line at four years represents only a slight increase in number at three and then at two years of age. This indicates that crown closure is expected at four years of age for the locusts, and that a lesser crown density is considered adequate for an equal degree of success in stands less than four years old.

The curves beneath the top one represent, in descending order, conditions with the number of black locusts being 80, 70, 60, 50, 40 and 30 per cent of the ideal.

In addition to number of trees, "per cent of stocking," which indicates the distribution of the locusts over the area, is also used. One hundred per cent stocking means that the locusts are evenly distributed over the entire area to give nearly complete crown cover. Ten per cent stocking means that the locusts occur on only one-tenth of the area, regardless of the total number of locusts. The per cent of stocking values used to indicate a certain degree of success are identical with the percentage of ideal numbers of evenly-spaced locusts which are used to indicate the same degree of success. The per cent stocking values necessary for the various degrees of success are shown in Figure 4, Test 2.

A successful stand of black locust is considered to be one which has at least 60 per cent of the ideal number of stems for the specified age and is 60 per cent stocked. Thus successful establishment of the locusts means that a two-year-old stand has at least 692 seedlings per acre, a three-year-old stand 631, a four-year-old stand 582, a five-year-old stand 381, a six-year-old stand 274, and seven-, eight-, nine- and ten-year-old stands have 209, 168, 140, and 115 stems per acre, respectively. All must be at least 60 per cent stocked.

When both the number of locusts and per cent stocking fall in areas, A, B, C, or D in Figure 4, Tests 1 and 2, establishment is considered a success. Areas E and F are indicative of Partial Success, and areas G. and H represent Failure.

Thus establishment of seeded black locust on the spoil banks is considered to be a failure when the per cent of stocking is less than 40, or when the number of stems is less than 461 at two years, less than 388 at four years and less than 93 at nine years.

APPENDIX TABLE 1. ABUNDANCE AND STOCKING OF BLACK LOCUST RESULTING FROM DIRECT SEEDING, BY INDIVIDUAL SPOIL BANKS

Name of Spoil		Date Seeded	Seedling Age at Time of Sampling	Area of Spoil	Total Spoil		Reverse Terrace		Outer Slope	
					No. Seedlings per Acre	Per Cent Stocking	No. Seedlings per acre	Per Cent Stocking	No. Seedlings per acre	Per Cent Stocking
Barbour	1	April '50	8	19.7	50	5	83	8	0	0
Boone	1	May '49	9	32.2	875	58	1125	75	750	50
"	2	May '52	6	42.3	950	77	636	64	1083	83
"	3	May '53	5	38.0	842	68	667	50	917	75
"	4	March '51	7	10.0	575	56	750	69	500	50
Braxton	1	May '53	5	8.7	0	0	0	0	0	0
"	2	October '49	8	14.2	500	50	500	50	500	50
Brooke	1	May '49	9	15.0	250	25	250	25	250	25
Clay	1	October '52	5	10.2	0	0	0	0	0	0
"	2	April '53	5	24.2	184	18	125	12	273	27
Fayette	1	May '52	6	17.8	139	16	188	19	91	9
"	2	June '53	5	3.8	740	71	800	73	700	70
"	3	March '53	5	11.3	752	71	938	75	667	67
"	4	August '49	8	19.1	628	60	562	56	778	67
"	5	December '48	9	30.0	752	73	562	50	833	83
"	6	May '54	4	27.7	375	38	375	38	375	38
"	7	May '54	4	28.0	318	31	312	31	333	33
"	8	November '53	4	12.0	525	47	312	31	667	58
"	9	March '51	7	167.1	615	58	625	56	600	60
"	10	May '56	2	3.3	334	34	375	38	273	27
Grant	1	May '52	6	5.5	200	20	....	....	200	20
Greenbrier	1	October '48	9	2.1	117	12	167	17	0	0
"	2	September '51	6	16.1	647	55	875	69	417	42
"	3	August '49	8	11.5	457	46	562	56	300	30
"	5	September '49	8	13.5	365	34	562	50	167	17
"	6	May '51	7	67.8	43	4	62	6	0	0

APPENDIX TABLE 1 (Cont'd.)

Name of Spoil		Date Seeded	Seedling Age at Time of Sampling	Area of Spoil	Total Spoil		Reverse Terrace		Outer Slope	
					No. Seedlings per Acre	Per Cent Stocking	No. Seedlings per acre	Per Cent Stocking	No. Seedlings per acre	Per Cent Stocking
Greenbrier	7	November '51	6	8.7	380	38	188	19	667	67
"	8	January '49	9	44.2	74	7	62	6	91	9
Harrison	1	August '49	8	5.2	0	0	0	0	......	....
"	2	October '49	8	6.9	427	43	375	38	583	58
Kanawha	1	March '56	2	26.2	521	47	62	6	750	67
"	2	April '52	6	47.9	438	38	375	36	500	40
"	3	June '53	5	34.3	493	47	867	80	333	33
"	4	May '53	5	50.4	750	64	750	56	750	67
Logan	1	September '49	8	13.3	600	60	250	25	723	73
McDowell	1	May '54	4	21.9	409	37	67	7	750	67
"	2	May '53	5	30.0	230	25	375	38	167	17
"	3	October '48	9	15.7	733	73	833	83	667	67
"	4	September '50	7	36.0	760	69	938	81	583	58
"	5	March '56	2	40.0	430	37	250	25	500	42
"	6	April '53	6	11.0	334	34	0	0	417	42
Mercer	1	June '49	9	5.5	133	13	333	33	0	0
"	2	March '50	8	11.0	653	56	750	67	556	44
"	3	November '49	8	19.5	105	10	125	12	91	9
"	4	April '52	6	22.6	345	34	375	38	333	33
"	5	May '55	3	6.5	94	9	83	8	111	11
"	7	April '50	8	10.4	875	83	917	83	833	83
Mineral	1	May '53	5	5.0	1006	74	1062	81	500	50
Mingo	1	March '53	5	50.8	442	36	500	44	417	33
"	2	June '49	9	95.1	558	48	500	44	583	50
"	3	March '50	8	7.0	698	60	312	25	1083	92
"	4	June '49	9	9.0	565	56	133	13	750	75
Monongalia	1	June '48	10	11.6	88	4	125	6	0	0
"	2	April '49	9	4.4	136	14	273	27	0	0

Name of Spoil		Date Seeded	Seedling Age at Time of Sampling	Area of Spoil	Total Spoil		Reverse Terrace		Outer Slope	
					No. Seedlings per Acre	Per Cent Stocking	No. Seedlings per Acre	Per Cent Stocking	No. Seedlings per Acre	Per Cent Stocking
Nicholas	1	January '50	8	19.0	630	44	812	56	83	8
"	2	October '50	8	27.0	854	71	938	75	600	60
"	3	April '49	9	16.7	480	48	667	67	200	20
"	4	April '50	8	5.3	750	62	1000	82	500	42
Ohio	1	April '53	5	7.5	2075	60	2000	69	2250	38
Pocahontas	1	May '56	2	64.8	100	10	0	0	167	17
Preston	1	September '49	8	16.0	283	28	250	25	333	33
"	2	May '53	5	20.0	338	34	375	38	250	25
"	3	May '52	6	13.3	667	46	250	19	1500	100
Putnam	1	October '51	6	7.9	688	60	875	69	500	50
Raleigh	1	December '48	9	10.0	271	27	125	12	417	42
"	3	April '51	7	20.3	150	15	250	25	0	0
"	5	April '53	5	11.3	708	63	625	50	833	83
"	6	June '50	8	15.1	543	54	438	44	700	70
"	7	April '53	5	23.6	196	20	812	31	167	17
"	8	April '53	5	22.8	537	54	467	47	583	58
"	9	July '53	5	6.0	348	35	188	19	417	42
"	12	May '52	6	22.7	556	52	688	56	500	50
Randolph	1	April '49	9	25.5	125	12	125	12	125	12
"	2	April '52	6	17.7	154	15	62	6	429	43
"	3	June '53	5	28.7	100	10	0	0	167	17
"	4	March '49	9	3.4	310	31	267	27	333	33
Tucker	1	March '49	9	24.0	898	44	1438	50	667	42
Webster	1	May '53	5	2.1	0	0	0	0	0	0
Wyoming	2	May '52	6	17.7	450	38	375	31	500	42
"	3	April '50	8	53.8	225	23	188	19	250	25
"	4	November '49	9	20.5	948	76	438	38	1167	92
Total				1823.4						
Weighted Averages:					464	40.4	434	37.2	499	43.5

Appendix Table 2. Abundance and Stocking of Naturally-Seeded Woody Species by Individual Spoil Banks

Name of Spoil		Total Spoil		Reverse Terrace		Outer Slope	
		No. Seedlings Per Acre	Per Cent Stocking	No. Seedlings Per Acre	Per Cent Stocking	No. Seedlings Per Acre	Per Cent Stocking
Barbour	1	50	5	83	8	0	0
Boone	1	664	55	1000	75	500	25
"	2	486	38	455	27	500	42
"	3	475	28	1001	67	250	25
"	4	1174	92	998	75	1248	100
Braxton	1	421	42	437	44	375	38
"	2	947	76	811	69	1082	83
Brooke	1	850	35	874	37	833	33
Clay	1	694	52	560	37	749	58
"	2	293	26	124	6	546	55
Fayette	1	730	56	810	56	546	55
"	2	1139	70	1199	73	1000	70
"	3	375	38	250	25	500	50
"	4	584	47	501	39	777	67
"	5	711	68	810	69	666	67
"	6	713	67	750	69	625	62
"	7	1000	58	811	56	1443	78
"	8	1100	83	873	69	1250	92
"	9	886	69	811	62	1000	70
"	10	591	59	623	62	546	55
Grant	1	1266	73	......	....	1266	73
Greenbrier	1	547	47	610	50	400	40
"	2	220	22	188	19	250	25
"	3	1616	93	1561	87	1700	100
"	5	1318	80	1125	69	1499	92
"	6	2058	87	2123	81	1909	100
"	7	1361	93	1438	94	1248	92
"	8	521	48	687	69	273	27

Name of Spoil		Total Spoil		Reverse Terrace		Outer Slope	
		No. Seedlings Per Acre	Per Cent Stocking	No. Seedlings Per Acre	Per Cent Stocking	No. Seedlings Per Acre	Per Cent Stocking
Harrison	1	166	17	166	17	......	....
,,	2	745	52	687	56	917	42
Kanawha	1	0	0	0	0	0	0
,,	2	1044	76	1186	81	900	70
,,	3	449	45	334	33	499	50
,,	4	154	15	125	12	166	17
Logan	1	999	72	1419	92	819	64
McDowell	1	67	7	133	13	0	0
,,	2	425	42	186	19	584	58
,,	3	267	27	499	50	111	11
,,	4	540	46	500	44	583	50
,,	5	78	8	67	7	83	8
,,	6	134	13	0	0	166	17
Mercer	1	533	53	500	50	555	56
,,	2	348	35	250	25	444	44
,,	3	536	48	248	25	728	64
,,	4	1200	85	499	50	1499	100
,,	5	94	9	83	8	111	11
,,	7	292	29	249	25	333	33
Mineral	1	662	55	625	56	1000	50
Mingo	1	616	36	500	44	667	33
,,	2	519	48	562	44	500	50
,,	3	198	14	312	19	83	8
,,	4	450	45	333	33	500	50
Monongalia	1	115	12	125	12	91	9
,,	2	308	26	364	27	250	25

APPENDIX TABLE 2 (Cont'd.)

Name of Spoil		Total Spoil: No. Seedlings Per Acre	Total Spoil: Per Cent Stocking	Reverse Terrace: No. Seedlings Per Acre	Reverse Terrace: Per Cent Stocking	Outer Slope: No. Seedlings Per Acre	Outer Slope: Per Cent Stocking
Nicholas	1	614	50	625	50	583	50
"	2	1146	72	1062	62	1400	100
"	3	800	64	800	67	800	60
"	4	1313	72	1374	69	1250	75
Ohio	1	1355	46	813	44	2625	50
Pocahontas	1	275	27	187	19	333	33
Preston	1	536	45	374	31	777	67
"	2	861	70	748	62	1125	88
"	3	2213	85	1250	50	2625	100
Putnam	1	812	66	624	56	1001	75
Raleigh	1	813	58	623	62	999	67
"	3	939	51	499	31	1600	80
"	5	490	45	374	31	669	67
"	6	698	58	498	44	1000	80
"	7	577	53	561	31	583	58
"	8	592	46	602	40	583	50
"	9	1077	77	1061	81	1083	75
"	12	697	58	186	19	915	75
Randolph	1	1024	75	874	62	1375	88
"	2	271	23	124	12	715	57
"	3	575	55	562	50	582	58
"	4	1288	93	1201	80	1335	100
Tucker	1	1520	71	1374	62	1581	75
Webster	1	695	62	834	67	555	56
Wyoming	2	724	58	560	44	832	67
"	3	400	35	499	50	333	25
"	4	77	8	62	6	83	8
Weighted Averages:		684	49.7	690	47.3	679	52.3

Appendix Table 3. Common and Technical Names of Trees and Shrubs

Common Name	Technical Name
Ailanthus	*Ailanthus altissima* (Mil.) Swingle
Alder, smooth	*Alnus serrulata* (Ait.) Willd.
Apple, sweet crab	*Malus coronaria* (L.) Mill.
Ash, green	*Fraxinus pennsylvanica* Marsh.
Ash, white	*Fraxinus americana* L.
Aspen, trembling	*Populus tremuloides* Michx.
Beech, American	*Fagus grandifolia* Ehrh.
Blackgum	*Nyssa sylvatica* Marsh.
Birch, black	*Betula lenta* L.
Birch, yellow	***Betula alleghaniensis*** Britton
Cherry, black	*Prunus serotina* Ehrh.
Cherry, fire	*Prunus pensylvanica* L. f.
Dogwood, flowering	*Cornus florida* L.
Elderberry	*Sambucus canadensis* L.
Elm, slippery	*Ulmus rubra* Muhl.
Hawthorn	*Crataegus* spp.
Hercules club	*Aralia spinosa* L.
Hickory	*Carya* spp.
Honey-Locust	*Gleditsia triacanthos* L.
Hornbeam	*Carpinus caroliniana* Walt.
Locust, black	*Robinia pseudoacacia* L.
Maple, red	*Acer rubrum* L.
Maple, striped	*Acer pensylvanicum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, black	*Quercus velutina* Lam.
Oak, chestnut	*Quercus prinus* L.
Oak, northern red	*Quercus rubra* L.
Pine, pitch	*Pinus rigida* Mill.
Pine, Virginia	*Pinus virginiana* Mill.
Pine, white	*Pinus strobus* L.
Redbud, eastern	*Cercis canadensis* L.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Serviceberry	*Amelanchier* spp.
Sumac	*Rhus* spp.
Sycamore	*Platinus occidentalis* L.
Willow	*Salix* spp.
Yellow-poplar	*Liriodendron tulipifera* L.

Appendix Table 4. Common and Technical Names of Herbaceous Plants

Common Name	Technical Name
Broomsedge	*Andropogon virginicus* L.
Cinquefoil, common	*Potentilla simplex* Michx.
Goldenrod, wrinkle-leaf	*Solidago rugosa* Ait.
Lespedeza, sericea	*Lespedeza sericea* (Thunb.) Benth.
Panic-grass	*Panicum* spp.
Pokeweed	*Phytolacca americana* L.
Poverty-grass	*Danthonia spicata* (L.) Beauv.
Redtop	*Agrostis alba* L.